tried with about the same results as for pure hydrogen. No evidence of any helium ions was observed.

A probable mechanism for the dissociation of the hydrogen is as follows. From work on accommodation coefficients of ions on metal surfaces it seems reasonable to suppose that the hundred volt ions striking the cylinder retain after neutralization between 80 and 90 percent of their kinetic energy. Since their masses are approximately equal to those of the gas atoms or molecules, they quickly reach thermal equilibrium with the gas, thus producing effectively a gas at a very high temperature. The chemical equilibrium data between atomic and molecular hydrogen as a function of pressure and temperature would then lead one to expect a high ratio of atomic to molecular hydrogen. At lower pressures most of the collisions of the high speed neutral particles are with the walls and thus the gas is not raised to the effective high temperature. The mechanism just outlined is quite possibly that responsible in part for the dissociation in the proton source reported recently by Oliphant and Rutherford.[3]

The proton source here reported is believed to possess certain advantages: first, the small voltages needed for its operation are obtainable from storage batteries and thus require no elaborate apparatus and second, the total power required is small, being less than one hundred watts.

E. S. Lamar
Overton Luhr

George Eastman Research Laboratories,
Massachusetts Institute of Technology,
November 14, 1933.

[3] Oliphant and Rutherford, Proc. Roy. Soc. **A141**, 259 (1933).

Li^+ Fine Structure and Wave Functions near the Nucleus

The fine structure of the $(1s2p)^3P$ level of Li^+ has been calculated by using for the unperturbed level wave functions built up from $F=r_1(1+c\cos\theta)\exp(-xr_1/2-yr_2/2)$ by multiplication with the proper angle functions and formation of the antisymmetric part of the products. a, x, and y were determined by the Ritz variational method. The energy of the spin-free state assumed its minimum value $-1.16404R_z$ for $x=0.3605$, $y=0.993$, $c=-0.009836$. The expressions for the spin-orbit and spin-spin interactions used previously[1] to calculate the fine structure of He were evaluated for this wave function and gave $C=-0.334$, $D=-1.040$ cm^{-1}. The energies of the triplet levels $j=0, 1, 2$ are $E_0+[-3(C+D), 2(D-C), 0]$, respectively, and the measurements of Schüler[2] give $C=0.016$, $D=-1.033$.

The variational process was conducted as follows. Since c is small and gives a very small contribution to the energy, it was first taken to be zero and x and y were varied, the values above giving a minimum energy. Keeping x and y fixed, the energy was then minimized with respect to c. The energy is very sensitive to a change in y, and the error in y caused by neglecting c can hardly exceed ± 0.001. It may be that the best value of x is shifted slightly by lifting the restriction $c=0$, but a change in x of even 0.0002 changes C and D by less than one part in 500. Thus disagreement between calculated and observed values of C is quite definitely present.

As in He the disagreement is much smaller for the spin-spin interaction D than for the spin orbit interaction C. In both cases this is due to the fact that the spin orbit interaction is a sum of two opposing effects having the same order of magnitude. One may suppose that to some extent this situation is general also for heavier atoms and one may express a doubt as to the exactness of nuclear magnetic moments derived by using approximate theoretical expressions for the spin-orbit interaction.

We are indebted to Mr. J. Leiner for help with the numerical computations.

John A. Wheeler
G. Breit

New York University,
University Heights,
November 15, 1933.

[1] G. Breit, Phys. Rev. **36**, 385 (1930).
[2] H. Schüler, Zeits. f. Physik **66**, 431 (1930).

The Production of Positives by Nuclear Gamma-Rays

The gamma-rays emitted by a nucleus may, when the energy of the rays is greater than the million volts necessary to produce a pair, be absorbed by the creation of an electron and a positive in the neighborhood of the nucleus. The probability of internal conversion by an atomic electron is very small for gamma-rays of high energy and elements of small atomic number, for this process depends essentially upon the Coulomb field of the nucleus and the consequent acceleration of the electron. In contrast to this atomic internal conversion, the production of pairs can occur even when the gamma-ray is emitted by a nucleus of negligible electrostatic field.

This circumstance makes possible a very simple calculation of the probability of internal absorption of the gamma-ray by pair production, in which one neglects entirely the effect upon electron and positive of the electrostatic field of the nucleus. A more detailed consideration shows that the results so computed should be valid whenever, for both particles of the pair, the quantity $2\pi Ze^2/hv$ is small; here v is the velocity of the particle, and Z the nuclear charge. For light elements the method will thus give trustworthy results whenever this absorption is important; but with the heavier radioactive elements the results may be expected to hold even reasonably well only for the hardest radioactive gamma-rays.

The probability of pair production depends a little, though not nearly as much as the atomic internal conversion, on whether the gamma-ray is a dipole or a quadripole ray. If γ, ϵ, ϵ', are the energies of gamma-ray, electron and positive, all in units mc^2, so that $\epsilon, \epsilon' \geq 1$ and $\gamma = \epsilon + \epsilon'$, this probability is

$$(\alpha/\pi\gamma^3)\int_1^{\gamma-1} d\epsilon\{2pp' + (\epsilon^2 + \epsilon'^2) \ln b\} \quad (1)$$

for a dipole gamma-ray, and

$$(\alpha/\pi\gamma^5)\int_1^{\gamma-1} d\epsilon\{8pp'(\epsilon\epsilon' - 1) + 3\gamma^2(\epsilon^2 + \epsilon'^2 - 2) \ln b\} \quad (2)$$

for a quadripole. Here

$$p = (\epsilon^2 - 1)^{\frac{1}{2}};\ p' = (\epsilon'^2 - 1)^{\frac{1}{2}};\ b = \gamma^{-1}(\epsilon\epsilon' + pp' + 1);\ \alpha = 2\pi e^2/hc.$$

For very high energy gamma-rays we obtain the asymptotic values

$$(2\alpha/3\pi)\{\ln(2\gamma) - 3/5\} \quad \text{and} \quad (2\alpha/3\pi)\{\ln(2\gamma) - 61/30\}$$

for dipole and quadripole, respectively.

In the approximation here considered, the distribution in energy, as given by (1) and (2), is symmetric between the two particles. Because the nuclear field repels the positives and attracts the electrons, the positives will in fact tend to have higher energies; and when the gamma-ray is not too near the threshold, the mean energy of the positives will exceed that of the electrons by about αZ mc^2. For high energies the two particles tend to come off within a small angle of each other, though this effect is much less pronounced than for the pairs created by a beam of gamma-rays. It should be emphasized that these results, and the formulae given, are very insensitive to changes in the field of the multipole, and the electrostatic field, in the immediate neighborhood of the nucleus.

We may apply this theory to the observations of Curie and Joliot[1] who detected positives from beryllium and aluminum bombarded by the alpha-particles of polonium. This bombardment is known, in the case of beryllium, to produce gamma-rays of energy somewhat over five million volts, and we may take the yield of gamma-rays to be roughly 3×10^{-5} per alpha-particle. For this case (1) and (2) agree in giving about 2×10^{-3} for the probability that a gamma-ray will produce a pair; and we are thus led to expect a yield of positives of about 6×10^{-9} per alpha-particle. This seems consistent with the observations; but quantitative data are not available. For aluminum, on the other hand, it is necessary to assume a yield of very high energy gamma-rays at least fifty times the known yield of disintegration protons to account for the number of positives observed. This, together with the circumstance that, in absolute disagreement with the expected symmetry of the energy distributions, practically no high energy electrons were observed, makes it almost certain that the positives observed were not produced as pairs by the radiation from the disintegrating nucleus, and wholly confirms the distinction made by Curie and Joliot between the positives observed in the two cases. The positives observed in aluminum are, from the point of view of present theory, altogether unexplained.

The intense gamma-ray of Th C″, with $\gamma\sim5$, is known by its atomic internal conversion to be a quadripole ray. Here (2), which should still be right in order of magnitude, gives 5×10^{-4} for the probability of pair production.

Leo Nedelsky
J. R. Oppenheimer

University of California,
November 18, 1933.

[1] I. Curie and F. Joliot, J. de Physique **4**, 494 (1933).

Hyperfine Structure in the Tantalum Arc Spectrum

The results given in this note were presented in full at the June, 1933, meeting of the American Physical Society in Chicago. The evidence leading to the determination of the value 7/2 for the nuclear spin of tantalum was not given in full in the published abstract.[1] This evidence is especially interesting since it was possible to determine the nuclear spin without any knowledge of the term analysis of the spectrum. A partial analysis has been published since.[2]

The spectrum was excited in a water-cooled Schüler tube, and the hyperfine structure resolved by means of a Fabry-Perot etalon. The two lines on which the chief evidence rests are λλ5997.24 and 6020.69. A reproduction of the original photograph of these lines, taken by the second author, is shown in Fig. 1, together with their microphotometer traces. The etalon separation was 5 mm. λ6020.69 can be interpreted only a transition between levels with J-values 1/2 and 3/2. The intervals can be fitted only if I is 7/2. The level scheme is shown in Fig. 2, in which the intervals and positions of components are given in cm^{-1}. The term identifications are from Kiess and Kiess. The agreement between the observed and calculated patterns is shown in Table I. (The measured

Table I.

Component	Position (obs.)	Intensity (obs.)	Position (calc.)	Intensity (calc.)
A	0	33	0	15.9
B	0.085	63	0.084	47.7
C	.193	100	.189	100
D	.355	65	.349	45.4
E	.419	61	.412	47.7
F	.495	41	.496	34.1

[1] Grace and McMillan, Phys. Rev. **44**, 325A (1933).
[2] Kiess and Kiess, Bur. Standards J. Research **11**, 277 (1933).